Standards for Color Legibility

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Effective color graphics are the essential front-end of the post-industrial information economy. In most applications, color is used to convey information about the shape of something. Since all visual shapes are defined by their color and the color of their background, information is lost if those color combinations make the shape difficult to see. Yet, until recently there seemed to be no reason to involve color in shape discrimination. Numerous studies had shown that discrimination of colored shapes, such as letters, only depended on the lightness contrast between shape and background.[1]

Let's call how readily a shape can be discriminated as its "legibility". The legibility of colored shapes appeared to depend only on lightness contrast because legibility was defined in terms of the time required for shape recognition. Color combinations of shapes and backgrounds that enabled more rapid recognition were considered more legible. Unfortunately, this definition overlooked the fact that color information is conveyed by slow conducting parvo-cellular visual pathways, while lightness contrast is conveyed by rapid conducting magno-cellular pathways. Thus when asked to respond as quickly as possible, decisions about shape were made primarily on the basis of the information that arrived first - the color information was not used. When color is involved, legibility can not be operationally defined in terms of processing speed.

In fact, legibility is more commonly defined in terms that relate to the number of visual pathways needed to convey enough information to enable recognition of shapes such as letters. That number depends on the size of the image, which is readily measured in terms of the size and distance (i.e. visual angle) of the letters. Thus the 20/20 system uses letters of standard color (black/white), lightness contrast, and various sizes, to measure observer acuity in terms of distance. With a standard observer, this procedure can be reversed to measure legibility in terms of distance.

Several studies have used observers with normal color vision and the method of limits to measure recognition distance thresholds of colored letters and other shapes viewed against colored backgrounds.[2] Colors of the printed shapes were standardized in terms of the Pantone System and the Natural Color System as illuminated by a close approximation to standard illuminant A. These legibility measurements differ markedly from those based on recognition time. Several color combinations were found to be significantly more legible than black/white for letters, symbols and line drawings. Therefore, color legibility can not depend only on lightness contrast. Indeed, the best. colorimetric prediction of legibility ® = .95) had a larger factor for chromaticity than for lightness contrast. A colorimetric standard to define color legibility looked promising.

However, this success was based only on combinations of the six primary colors: black, white, red, yellow, green, blue. When 100 color combinations that included intermediate colors (like orange) and some saturation and lightness variations (like pink and brown) were tested, legibility could no longer be predicted from colorimetry.[3] The best equations could account for barely one-third of the variance. There is no colorimetric solution to color legibility.

One way then to ensure color legibility is to establish a guideline list of color combinations and their legibility distance thresholds. Since legibility distances involve the same metric as 20/20 descriptions of acuity, minimal legibility criteria for such a list could be set on the basis of the acuity of intended viewers and the viewing conditions. Following the example of the 20/20 system, the distance threshold of black/white could be used as a reference, and the other colors rated according to the ratio of their distance thresholds to that of black/white. This ratio varies somewhat from subjective evaluations of legibility - more noticeably so the greater its difference from 1/1. The reason becomes clear when one considers that legibility distances are not proportional to retinal image area and the number of visual pathways required for recognition. An inverse ratio of legibility distances-squared, "relative legibility", provides a better fit to subjective judgements.

The problem with a standard legibility list is the vast number of colors. Expanding such alist from 100 selected color combinations to the combinations of even a few hundred colors would be an impossible task. A general solution to establishing standards for color legibility is needed.

An alternative is a dynamic standard that specifies a certain method of measuring legibility. The method proposed uses observers who are similar to a standard observer and a legibility reference standard which for printed text would be a certain message printed in black/white using a font such as Helvetica Medium. The procedure uses the method of limits to measuring legibility distance thresholds. The colored targets are illuminated by a standard source such as illuminant A, which is readily approximated by 100 watt incandescent bulbs. This illumination should be incident from 45 degrees on each side as recommended by ASTM: D1729-89 to ensure uniformity. Further specification of the apparatus and procedure to include font size, source distance, geometry of an enclosure to eliminate glare and stray light, motion speed and available distance, a minimum standard error, etc. also need to be considered and involve some interactions. (A 35 pt font, 8 meter range, and 14 cm/sec speed were a suitable combination using readily available technology.)

The proposed standard method would compare the legibility distance threshold of any color combination displayed as text to the threshold of the black/white standard. It could also be used for symbols and other graphics. Acceptability of any color combination would require an agreed minimum relative legibility value such as 68%. The proposed method would be robust since slight differences that changed legibility distance of the tested colors would have a similar effect on the standard.

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